3D Environmental Audio With OpenAL

OpenAL Overview

Session 205

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Graphics and Media

3D Environmental Audio With OpenAL

OpenAL Overview

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https://developer.apple.com/wwdc2005

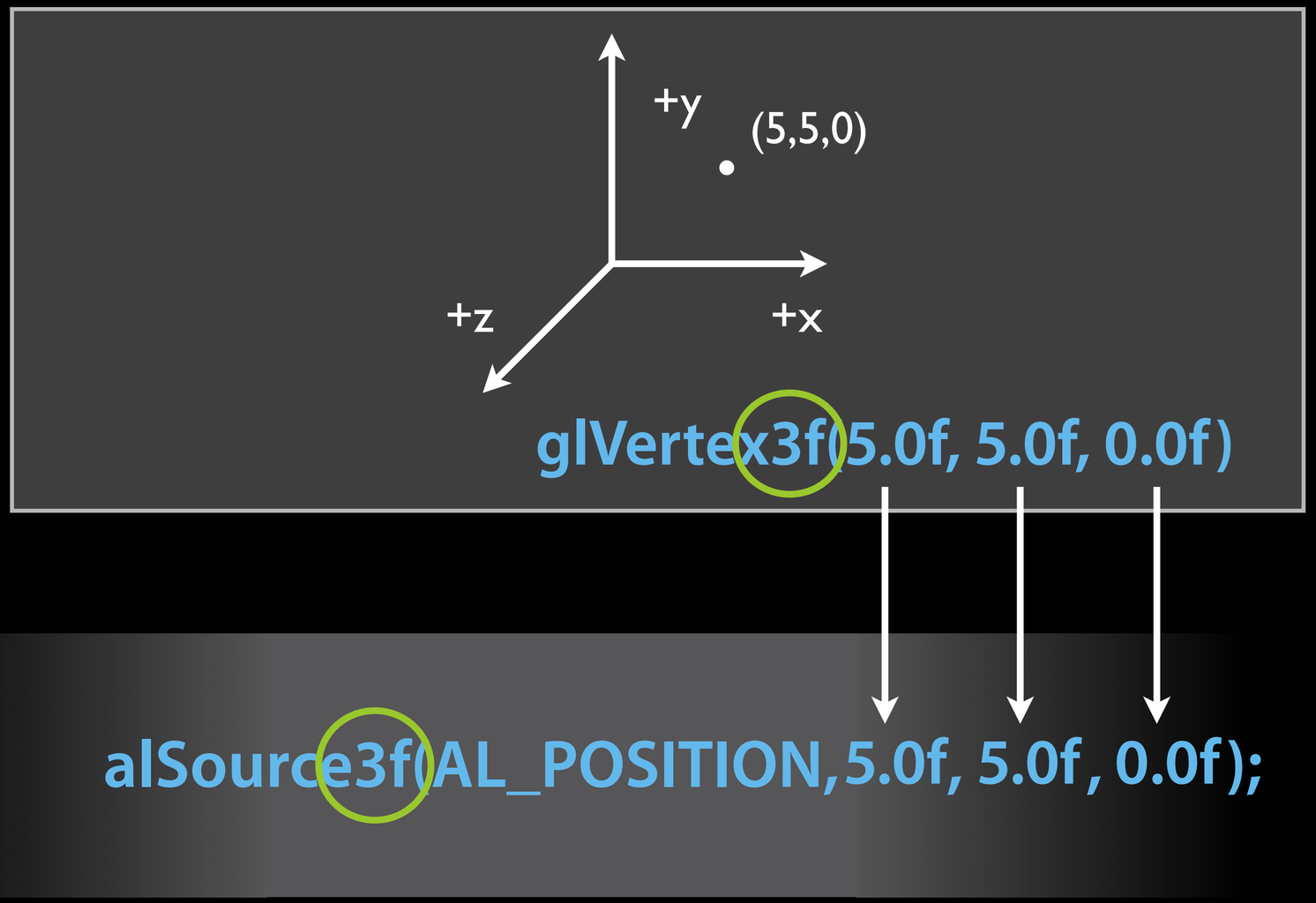
What Is OpenAL?

- Cross Platform 2D and 3D Audio API
- Compliment to OpenGL
- Open Source
  - http://www.openal.org
- Shipping with Tiger as OpenAL.framework
  - Compatible with Mac OS X 10.2.8 or greater

Main Features

- Stereo and Surround Sound
- Positional Audio
- Distance-Based Attenuation
- Pitch Changing

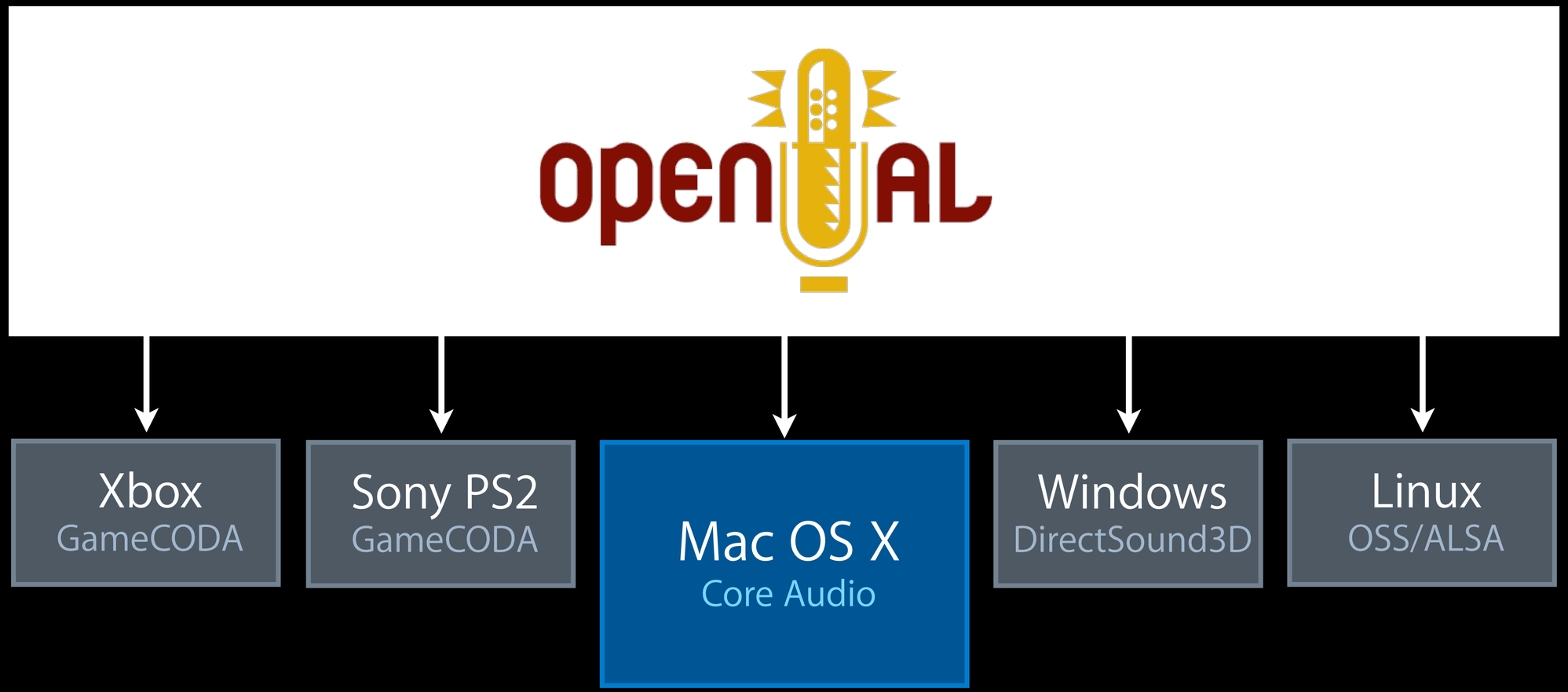
Same Coordinate System as OpenGL



Similar API Conventions

Built With the Power of Core Audio

Cross Platform



For full listing of platforms: http://www.openal.com/platforms.html

Shipped Using OpenAL

	Macintosh	Windows	Linux	FreeBSD	Irx
AlienFlux	●	●	●		
America's Army Operations	●	●	●		
A Tale in the Desert II	●	●	●		●
Blender 3D	●	●	●	●	
Dark Horizons: Lore	●	●	●		
Escape From Monkey Island	●				
Feeding Frenzy	●				
Harry Potter and the Chamber of Secrets	●	●			
Jedi Knight: Jedi Academy	●	●			
Jedi Knight 2	●	●			
Marble Blast	●	●	●		
MegaCorps Online	●	●	●		
Orbz	●	●	●		
Unreal Tournament 2003	●	●	●		
Unreal Tournament 2004	●	●	●		
XPlane	●	●	●		

Game Engines and Libraries

- AgentAE
- C4 Engine
- Lightweight Java Game Library
- Torque Engine
- Unreal Engine

Developer Story

Ryan Gordon
Feeding Frenzy

https://developer.apple.com/wwdc2005

OpenAL Architecture and Mac OS X Implementation

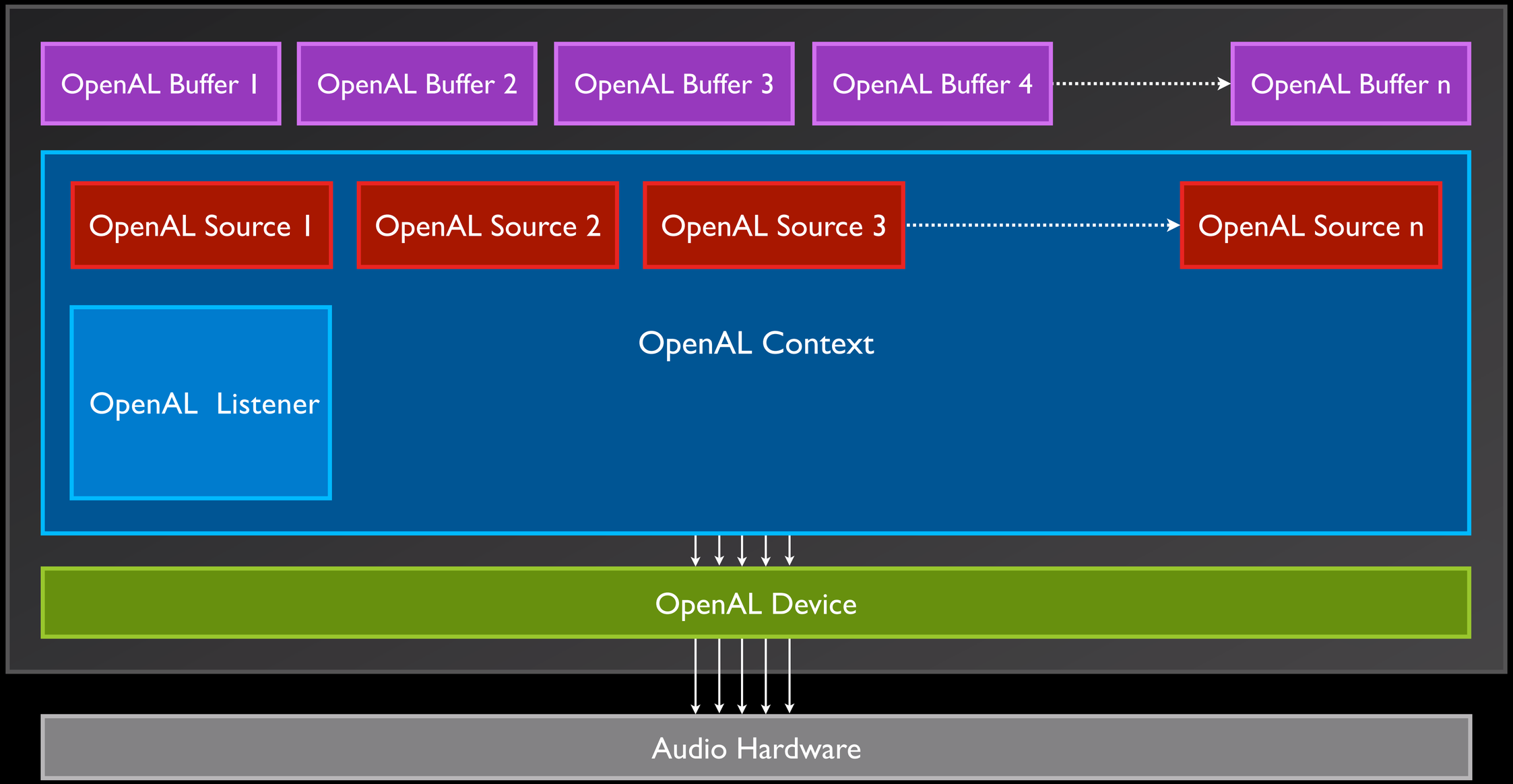
Bob Aron
Core Audio Engineer

https://developer.apple.com/wwdc2005

What You'll Learn

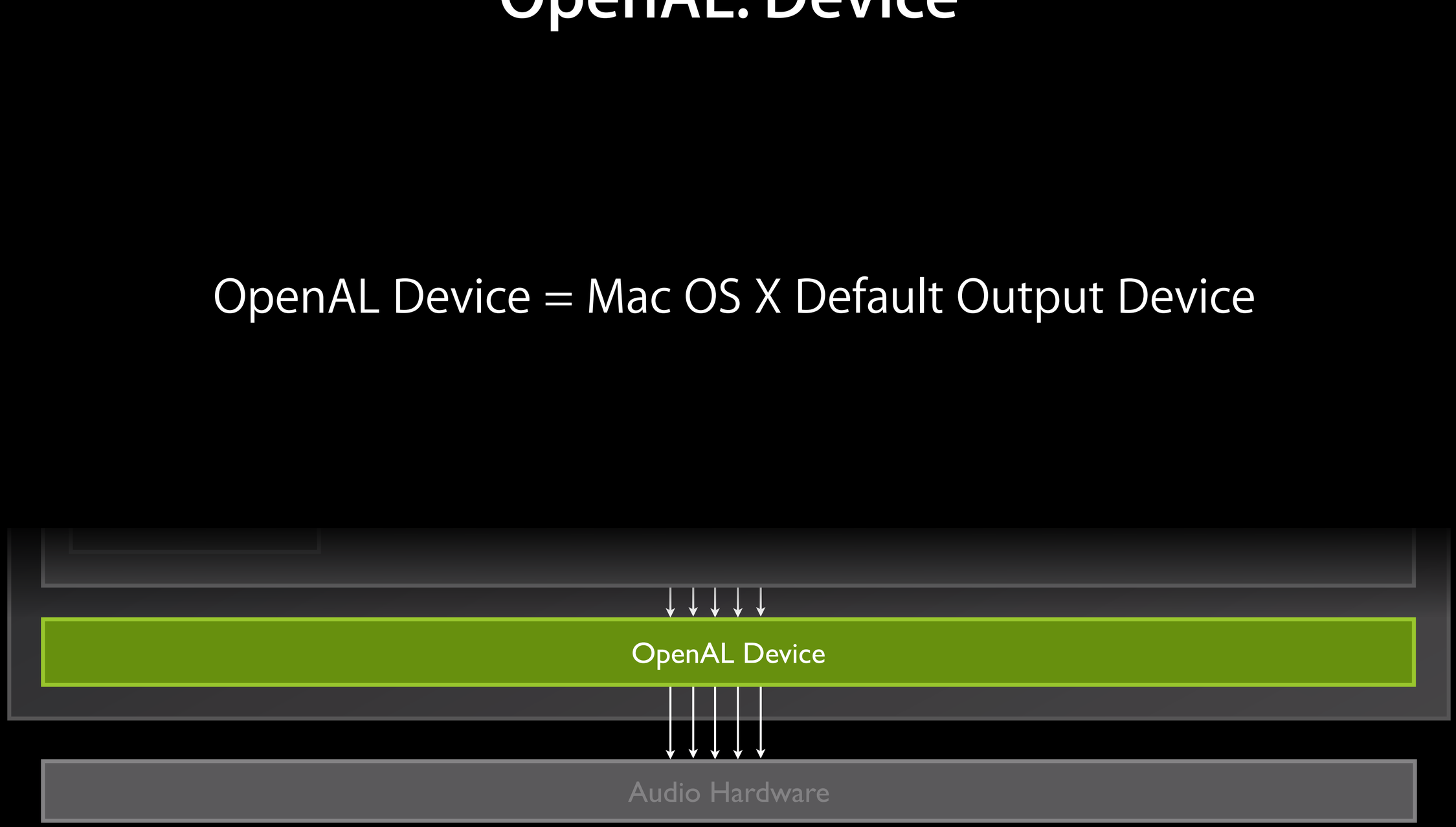
- OpenAL architecture
  - The virtual sound environment
  - Essential APIs
- OpenAL is a powerful audio engine everywhere
  - Difficult spatial rendering work done in the implementations
  - Applications require NO audio hardware knowledge
  - How Core Audio makes OpenAL great on Mac OS X

OpenAL Environment



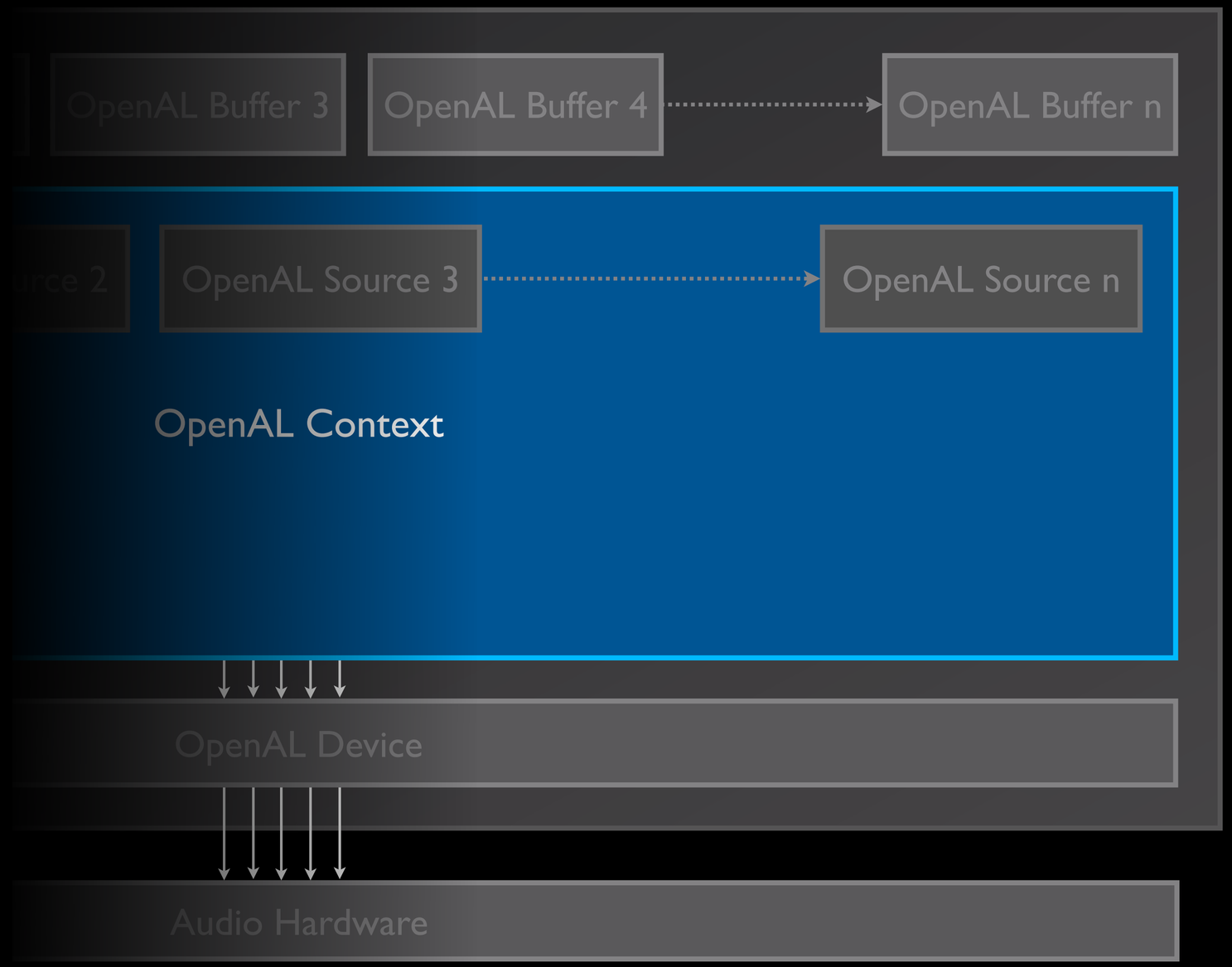
OpenAL: Device

OpenAL Device = Mac OS X Default Output Device



OpenAL: Context

- Objects Making Sound
- Environmental Settings
- Talks to OpenAL Device

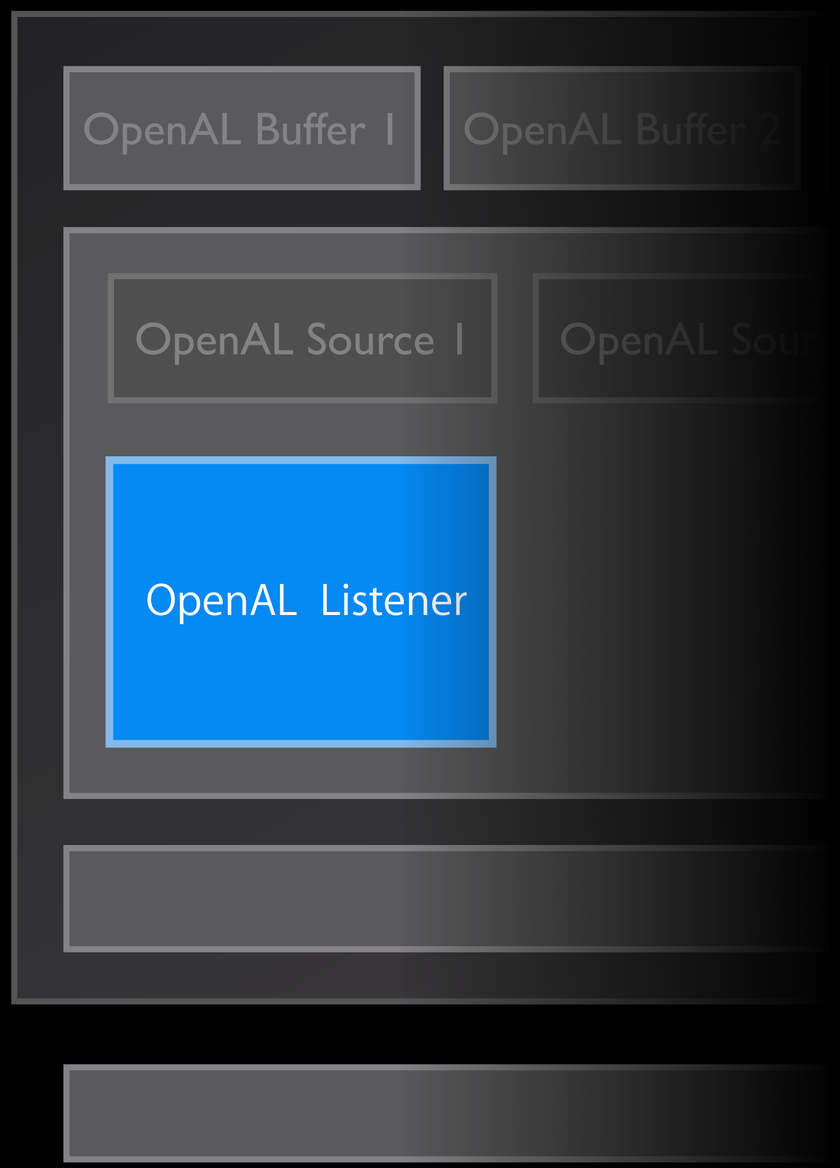


OpenAL: Devices and Contexts

- Opening/Closing an OpenAL Device
  - `ALCdevice* alcOpenDevice(ALCubyte *deviceName)`
  - `ALCvoid   alcCloseDevice(ALCdevice *device)`
- Creating/Destroying an OpenAL Context
  - `ALCcontext*  alcCreateContext( ALCdevice *device, ALCint   *attrList)`
  - `ALCvoid      alcDestroyContext (ALCcontext *context)`
- Making an OpenAL Context ‘Current’
  - `ALCboolean   alcMakeContextCurrent(ALCcontext *context)`

Demo Code: Initializing OpenAL, Part 1

```
void InitializeOpenAL()
{
  // Create a new OpenAL Device using the Default Output Device
  ALCdevice  *newDevice = alcOpenDevice(NULL);
  if (newDevice != NULL)
  {
    // Create a new OpenAL Context
    ALCcontext  *newContext = alcCreateContext(newDevice, 0);
    if (newContext != NULL)
    {
      // Make the new context the Current OpenAL Context
      alcMakeContextCurrent(newContext);
      // Create some OpenAL Source objects
      alGenBuffers(NUM_BUFFERS_SOURCES, gBuffers);
      // Create some OpenAL Buffer objects
      alGenSources(NUM_BUFFERS_SOURCES, gSources);
    }
  }
}
```



OpenAL Listener

- Only ONE Listener per Context
- Positionable in Virtual Space
- The User's Experience of the Virtual Space

OpenAL Listener: Orientation

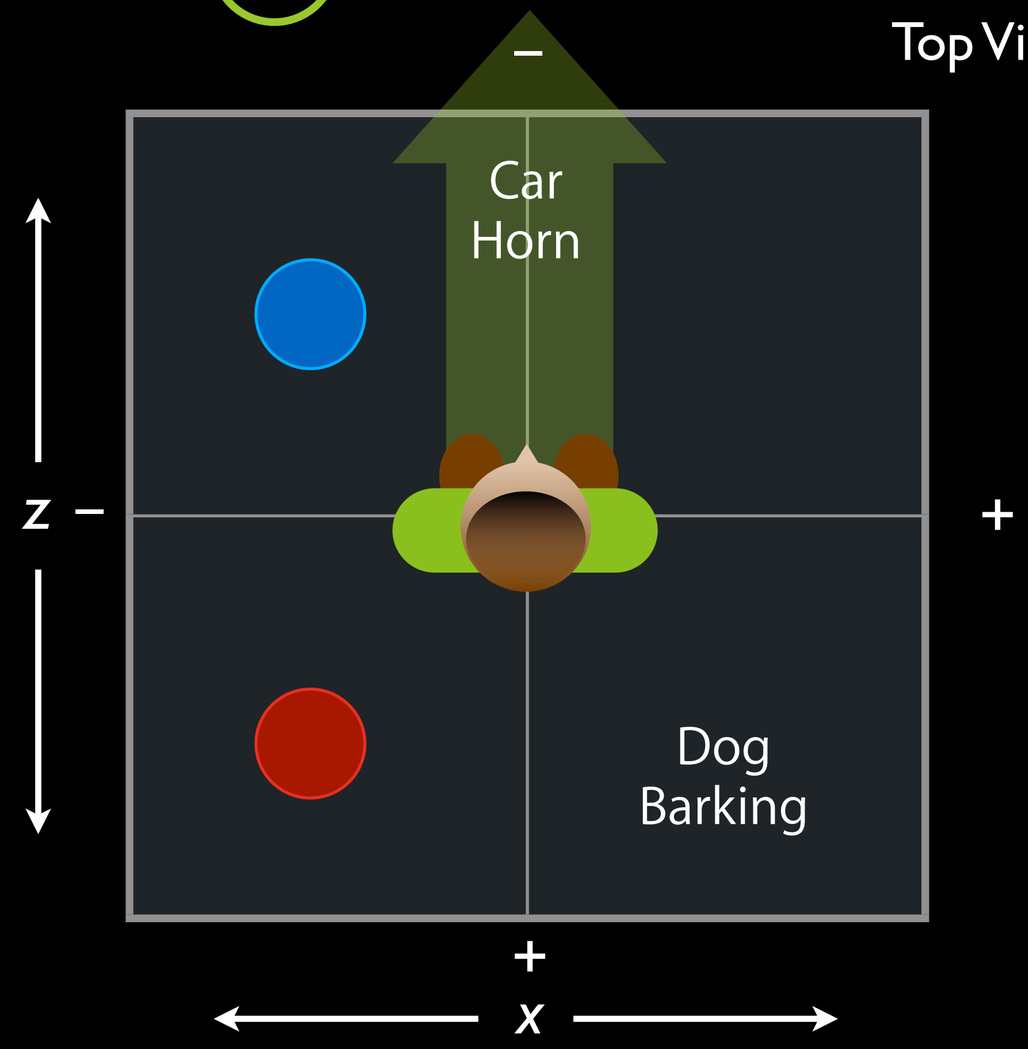
AL_ORIENTATION

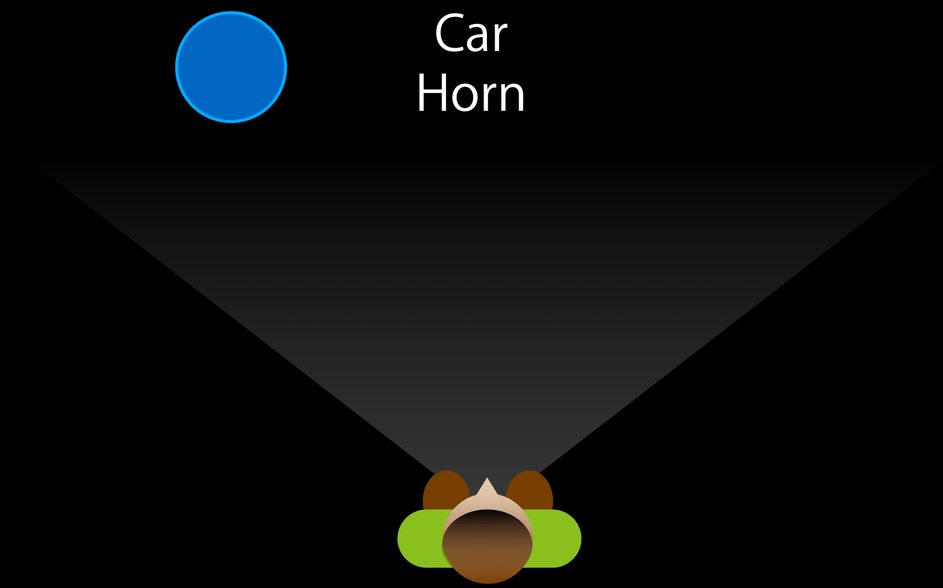
- OpenAL AL_ORIENTATION = OpenGL : gluLookAt()
- Render Audio Appropriately to the User's Speakers
- Described by two Vectors:
  - AT = Direction the Listener is facing
  - UP = Direction pointing up from the top of the Listener's head
  - Vectors are Orthogonal

```
// Orient the Listener Upside Down (-Y) and facing +Z
ALfloat listenerOrientation[6] = { 0.0, 0.0, 1.0,    // AT vector +Z
                                   0.0, -1.0, 0.0}    // UP vector -Y
alListenerfv(AL_ORIENTATION, listenerOrientation);
```

OpenAL Listener: Orientation

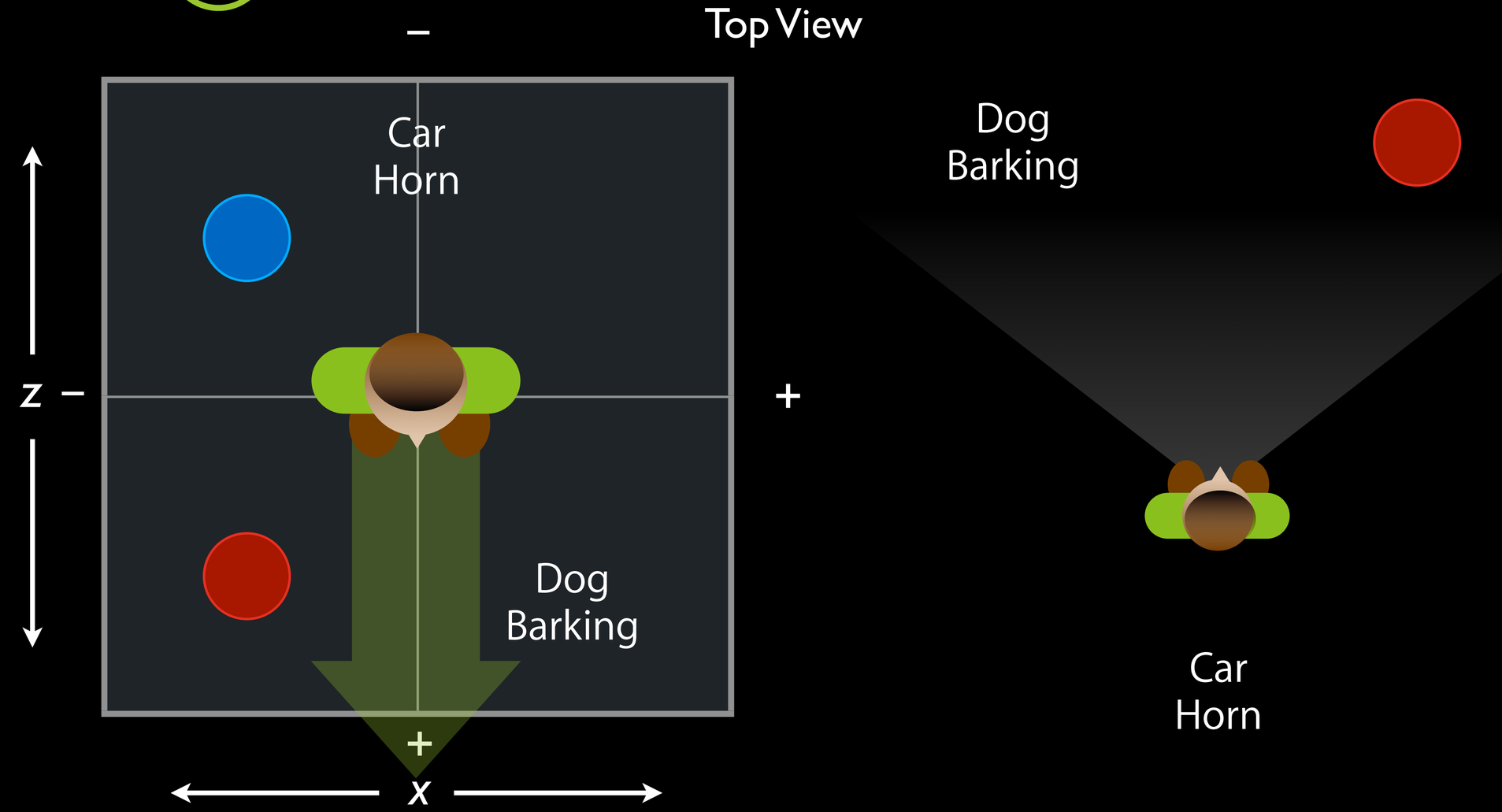
x:0, y:0, z: -1 = Listener facing Negative Z

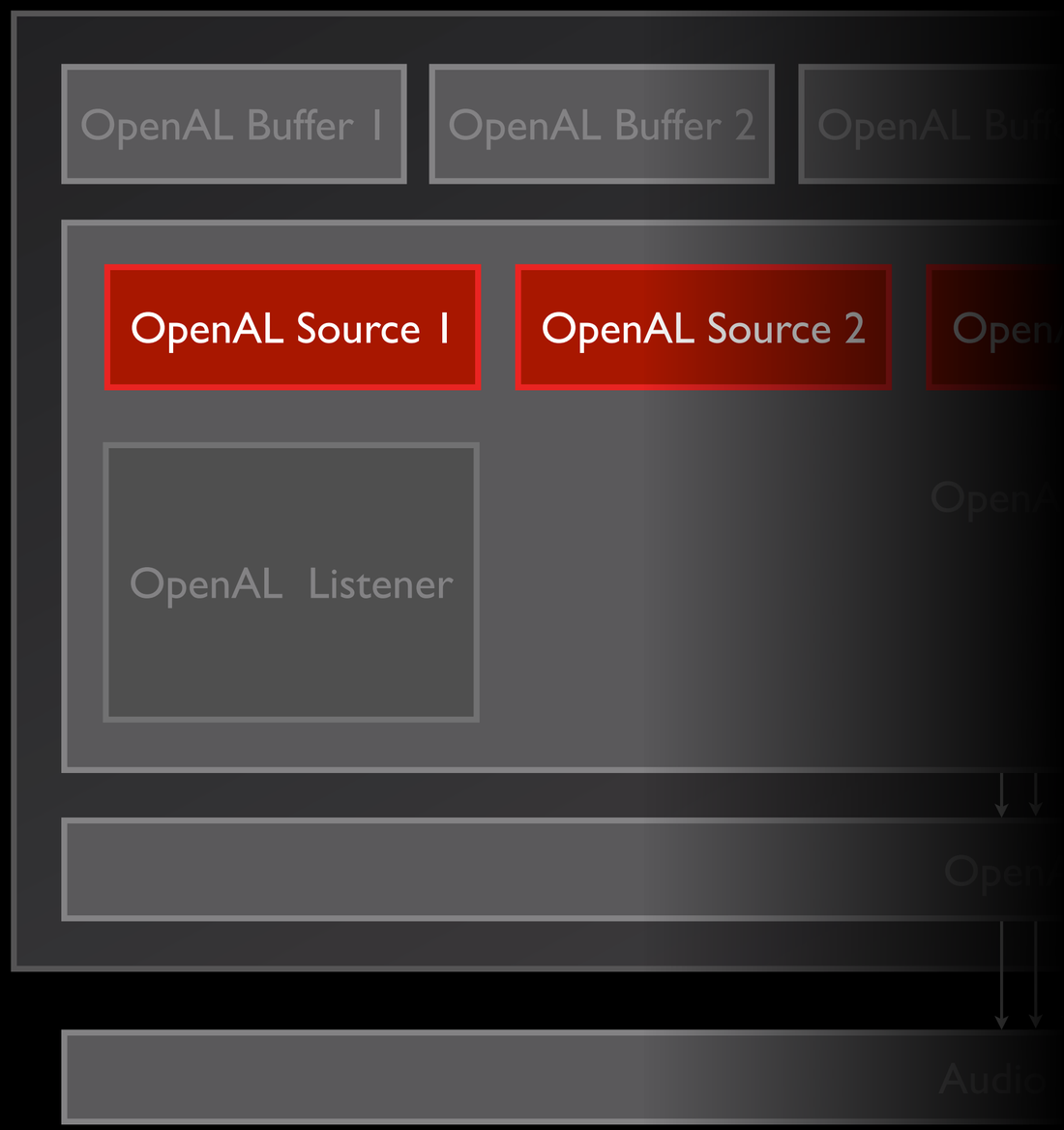




OpenAL Listener: Orientation

x:0, y:0, z:+1 = Listener facing the Positive Z





OpenAL Source

- Sources Make Sound!
- Owned by ONE Context
- Positionable in the Virtual Space
- Many Attributes to Control Rendering

OpenAL Source

Creating/Deleting OpenAL Sources

- ALvoid alGenSources(ALsizei n, ALuint *sources)
- ALvoid alDeleteSources (ALsizei n, ALuint *sources)

```
// Create 5 New OpenAL Sources
ALuint nuSources[5];
alGenSources(5, nuSources); → = {100, 101, 102, 103, 104}

// Delete 2 OpenAL Sources
ALuint deadSources[2] = {100, 102};
alDeleteSources(2, deadSources);
```

OpenAL Source/Listener: Position

AL_POSITION

- Applied to Listener
- Applied to Sources rendering Mono Audio Data
- Defined in World Coordinates. Center = {0.0, 0.0, 0.0}
- Right Handed Cartesian Coordinate System

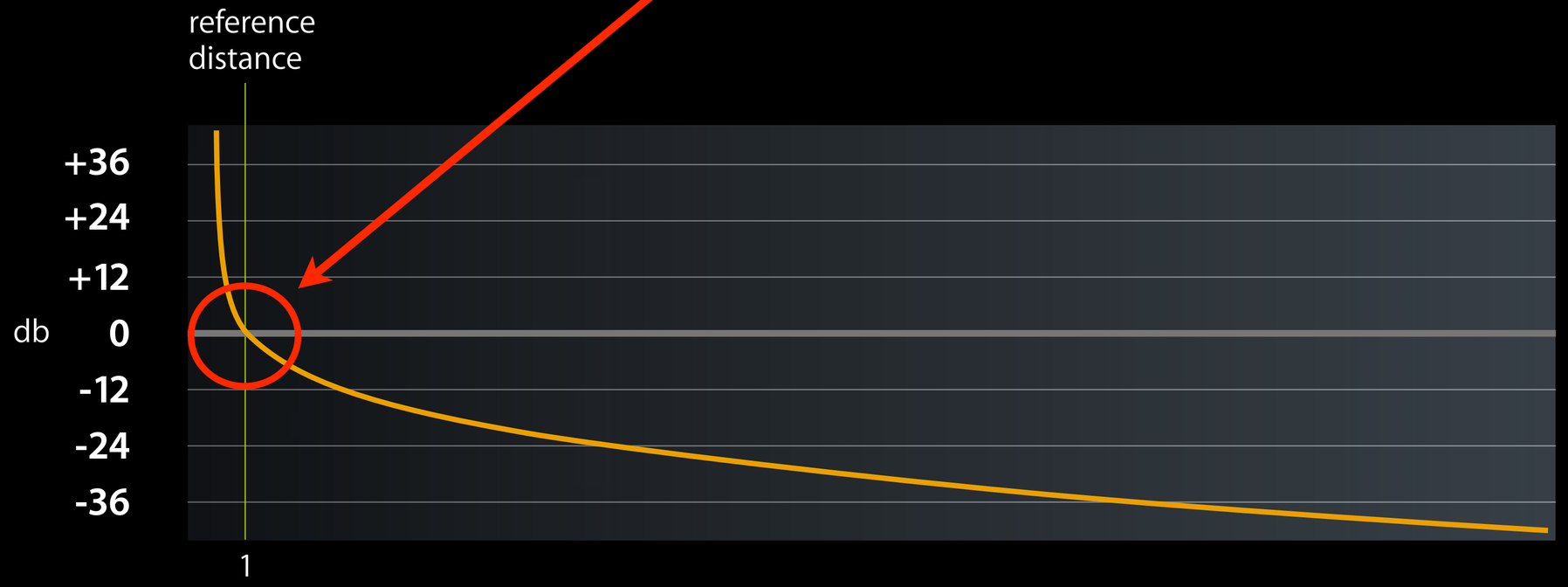
OpenAL: Attenuation by Distance

- Context Settings (Applied to all Sources)
  - Distance Model: `alDistanceModel()`
    - `AL_INVERSE_DISTANCE`
    - `AL_INVERSE_DISTANCE_CLAMPED`
    - `AL_NONE`
- Source Settings
  - `AL_REFERENCE_DISTANCE`
  - `AL_MAX_DISTANCE`
  - `AL_ROLLOFF_FACTOR`
  - `AL_SOURCE_RELATIVE`

OpenAL: Attenuation by Distance

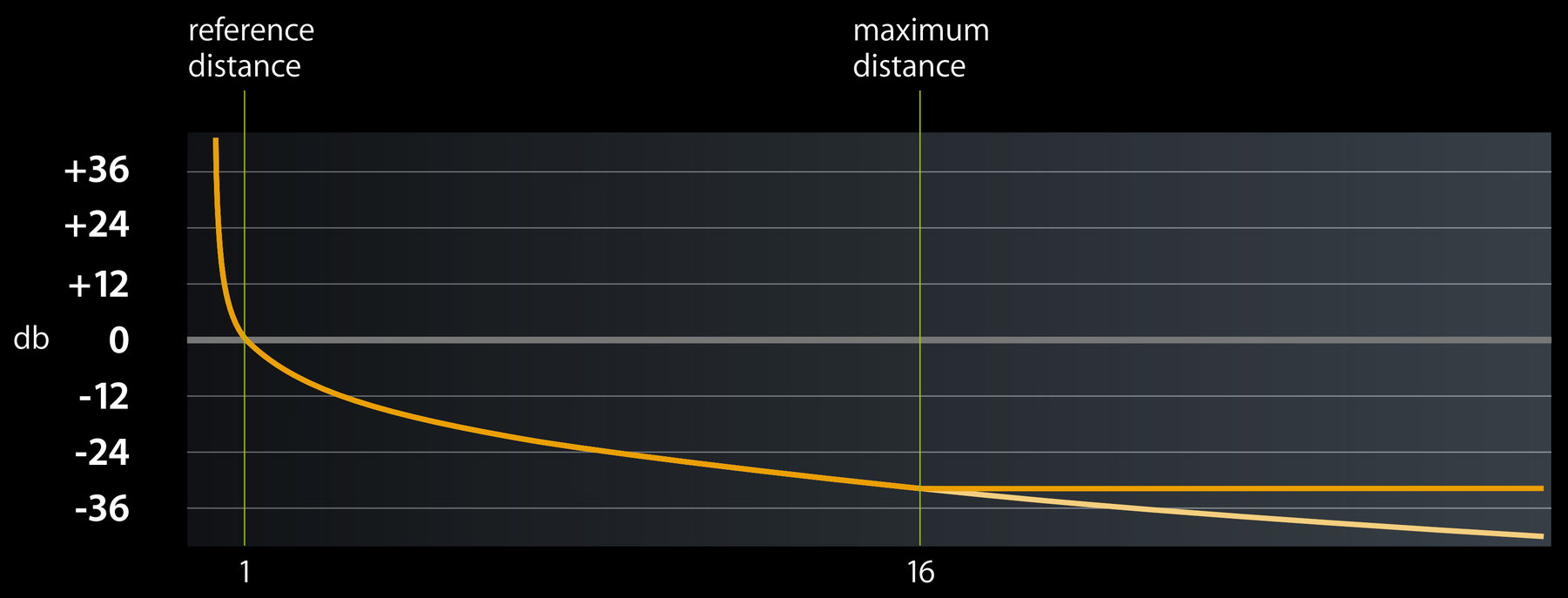
```
// SOURCE SETTING: Get the Source's Reference Distance
ALfloat refDistance;
alGetSourcef(mySource, AL_REFERENCE_DISTANCE, &refDistance);
```

= 1.0



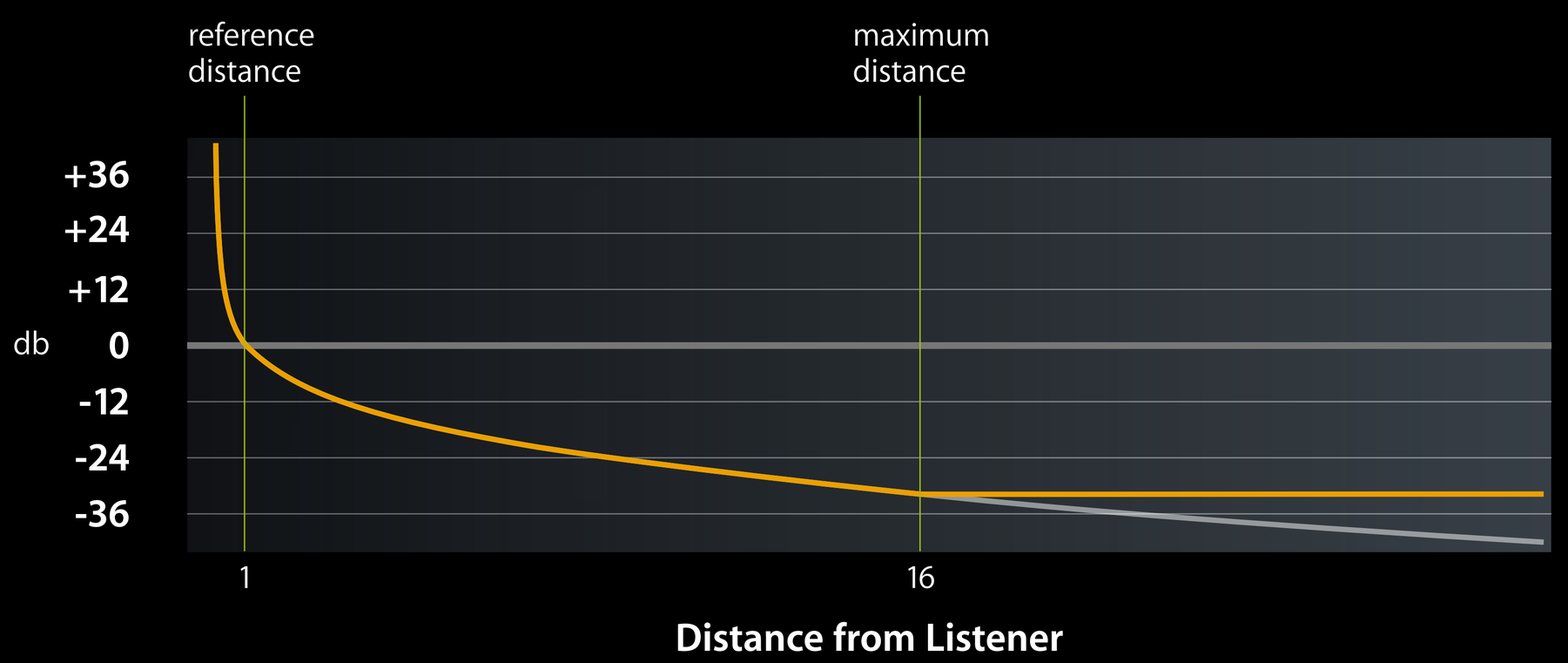
OpenAL: Attenuation by Distance

```
// SOURCE SETTING: Set the Maximum Distance to 16.0
alSourcef(mySource, AL_MAX_DISTANCE, 16.0);
```



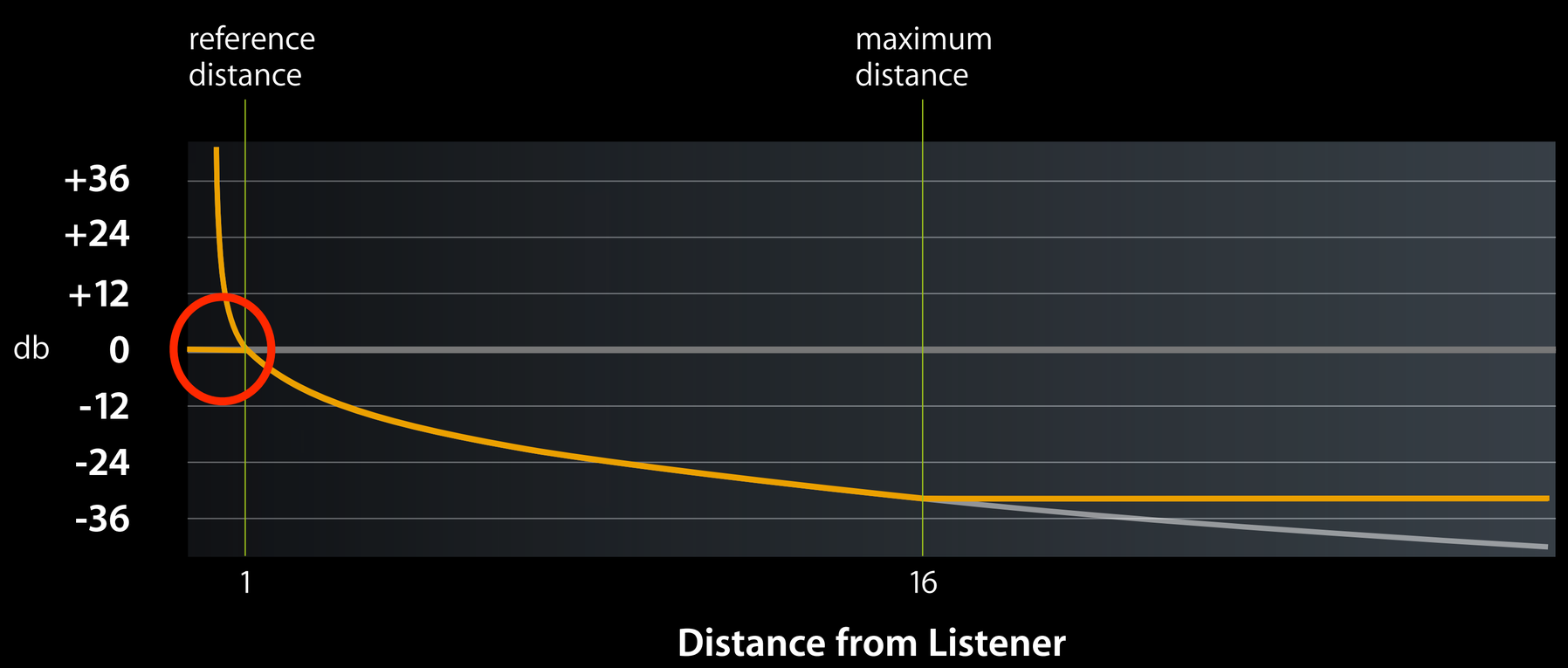
OpenAL: Attenuation by Distance

```
// CONTEXT SETTING: Set the Context Distance Model to AL_INVERSE_DISTANCE_CLAMPED
alDistanceModel(AL_INVERSE_DISTANCE_CLAMPED);
```



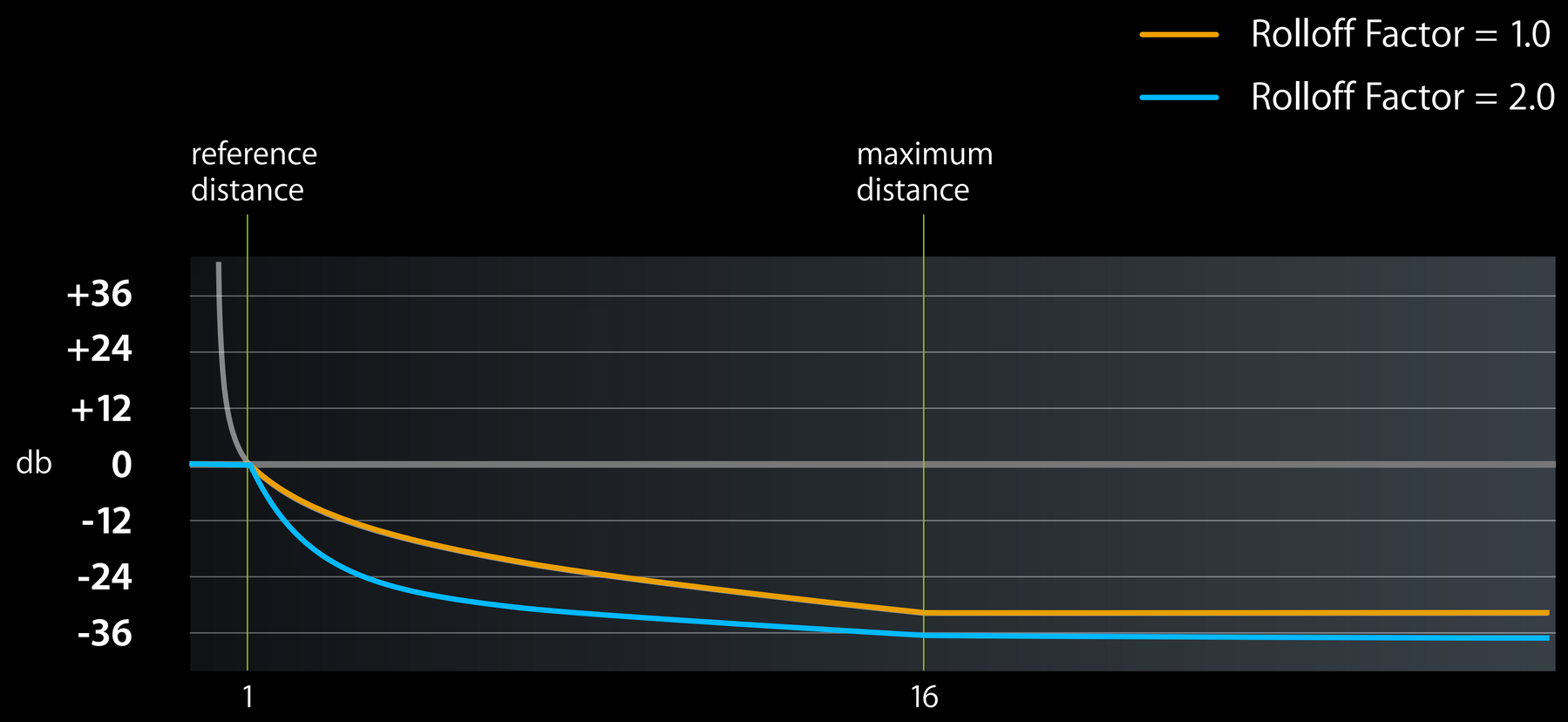
OpenAL: Attenuation by Distance

```
// CONTEXT SETTING: Set the Context Distance Model to AL_INVERSE_DISTANCE_CLAMPED
alDistanceModel(AL_INVERSE_DISTANCE_CLAMPED);
```



OpenAL: Attenuation by Distance

```
// SOURCE SETTING: Change the Source's Rolloff Factor
alSourcef(mySource, AL_ROLLOFF_FACTOR, 2.0);
```



OpenAL Source/Listener: Gain

AL_GAIN

- A Volume Scalar applicable to Source & Listener objects
  - Range: (0.0 - 1.0) = Silence to Full Volume
  - Listener Gain applied to all Context Sources
- `AL_MIN_GAIN / AL_MAX_GAIN:` Source ONLY attribute for bounding gain

```
// Set the Gain of the Source Object to .8
alSourcef(mySource, AL_GAIN, 0.8);
```

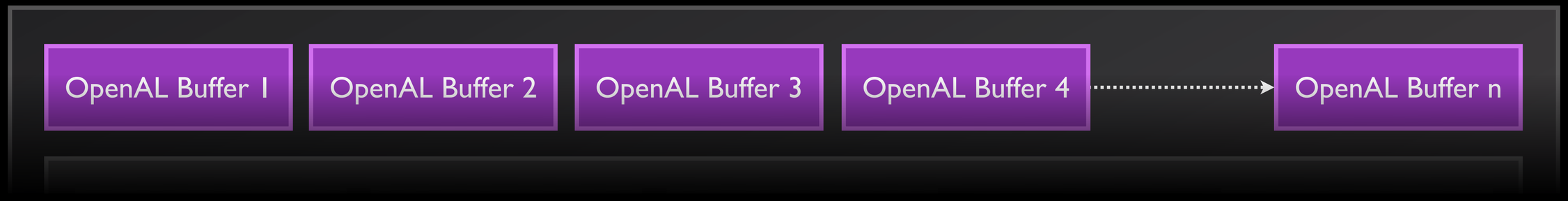
OpenAL Source: Pitch

AL_PITCH

- A Rate Scaler for data rendered by an OpenAL Source
  - 1.0 = NO Pitch Change (default)
  - Settable while rendering

```
// Double the pitch of the source object
alSourcef(mySource, AL_PITCH, 2.0);
```

OpenAL Buffer



- Containers of Audio Data
- Library Makes Copy of the Data
- Reusable
- Shared by ALL Source Objects

OpenAL Buffer

- Creating/Deleting OpenAL Buffers
  - `ALvoid alGenBuffers ( ALsizei n, ALuint *buffers)`
  - `ALvoid alDeleteBuffers ( ALsizei n, ALuint *buffers)`

- Adding Data to an Audio Buffer
  - `ALvoid alBufferData ( ALuint buffer, ALenum format, ALvoid  *data, ALsizei size, ALsizei freq)`

```
AL_FORMAT_MONO8
AL_FORMAT_STEREO8
AL_FORMAT_MONO16
AL_FORMAT_STEREO16
```

Required formats for all implementations

Important Note: Stereo data is ALWAYS rendered to the User's Front Speakers (L,R), regardless of Position or Listener Orientation settings.

OpenAL Source: Managing Buffers

- Adding/Removing OpenAL Buffers
  - `AL_BUFFER`
  - `alSourceQueueBuffers()`
  - `alSourceUnqueueBuffers():`
- Querying Queue State
  - `AL_BUFFERS_PROCESSED`
  - `AL_BUFFERS_QUEUED`
- Looping
  - `AL_LOOPING`

OpenAL Source: Managing the Buffer Queue

```
// Buffer Q already has 2 elements
```

Buffer 1 | Buffer 2

```
// Add 3 more buffers to the Queue
ALuint bufferArray[3] = {bufferOne, bufferThree, bufferFour};
alSourceQueueBuffers(mySource, 3, bufferArray);
```

Buffer 1 | Buffer 2 | Buffer 1 | Buffer 3 | Buffer 4

```
// Check the Q length                                    = 5
ALuint qLength;
alGetSourcei(mySource, AL_BUFFERS_QUEUED, &qLength);
```

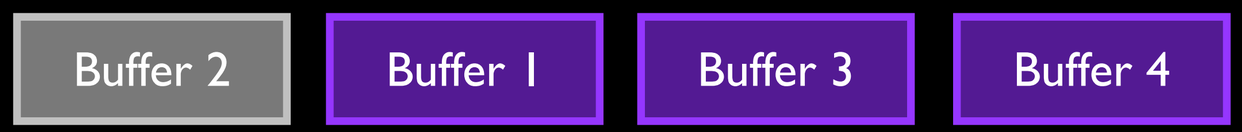
OpenAL Source: Managing the Buffer Queue

```
// check the processed buffers
ALuint processedCount;
alGetSourcei(mySource, AL_BUFFERS_PROCESSED, &processedCount);
```

= 2

```
// remove the 1st buffer in the queue
ALuint bufferArray[1];
alSourceUnqueueBuffers(mySource, 1, bufferArray);
```

bufferArray[0] = bufferOne

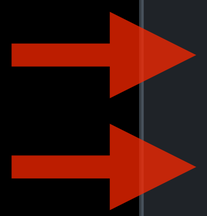


OpenAL Source: Playback Control

- Playing Audio
  - `ALvoid alSourcePlay (ALuint source)`
- Stopping Audio
  - `ALvoid alSourceStop (ALuint source)`
- Pausing Audio
  - `ALvoid alSourcePause (ALuint source)`
  - `ALvoid alSourceResume (ALuint source)`
- Rewinding Audio
  - `ALvoid alSourceRewind (ALuint source)`

Demo Code: Initializing OpenAL, Part 2

```
void InitializeOpenAL()
{
  // Create a new OpenAL Device using the Default Output Device
  ALCdevice  *newDevice = alcOpenDevice(NULL);
  if (newDevice != NULL)
  {
    // Create a new OpenAL Context
    ALCcontext  *newContext = alcCreateContext(newDevice, 0);
    if (newContext != NULL)
    {
      // Make the new context the Current OpenAL Context
      alcMakeContextCurrent(newContext);
      // Create some OpenAL Buffer objects
      alGenBuffers(NUM_BUFFERS_SOURCES, gBuffers);
      // Create some OpenAL Source objects
      alGenSources(NUM_BUFFERS_SOURCES, gSources);
    }
  }
}
```



Demo Code: Filling the Buffers

```
void InitializeBuffers()
{
  ALenum  format;
  ALvoid* data;
  ALsizei size, freq;
  UInt32 i;

  for (i = 0; i < NUM_BUFFERS_SOURCES; i ++)
  {
    // get some audio data from a file
    getAudioFileData(gSourceFile[i], &format, &data, &size, &freq);

    // Attach Audio Data to an OpenAL Buffer
    alBufferData(gBuffer[i], format, data, size, freq);

    // Release the audio data - OpenAL has made it's own copy
    releaseAudioFileData(data);
  }
}
```

Demo Code: Initialize Sources and Play

```
void InitializeSourcesAndPlay()
{
  UInt32   i;
  for (i = 0; i < NUM_BUFFERS_SOURCES; i++)
  {
    // Add a Buffer to the Source's Buffer Q
    alSourcei(gSources[i], AL_BUFFER, gBuffers[i]);
    // Turn Buffer Q Looping ON
    alSourcei(gSources[i], AL_LOOPING, AL_TRUE);
    // Set Position
    alSourcefv(gSources[i], AL_POSITION, gSourcePositions[i]);
    // Set Reference Distance to 5.0
    alSourcef(gSources[i], AL_REFERENCE_DISTANCE, 5.0f);
    // Start Playing the Sound
    alSourcePlay(gSources[i]);
  }
}
```

Demo

https://developer.apple.com/wwdc2005

OpenAL: Extensions

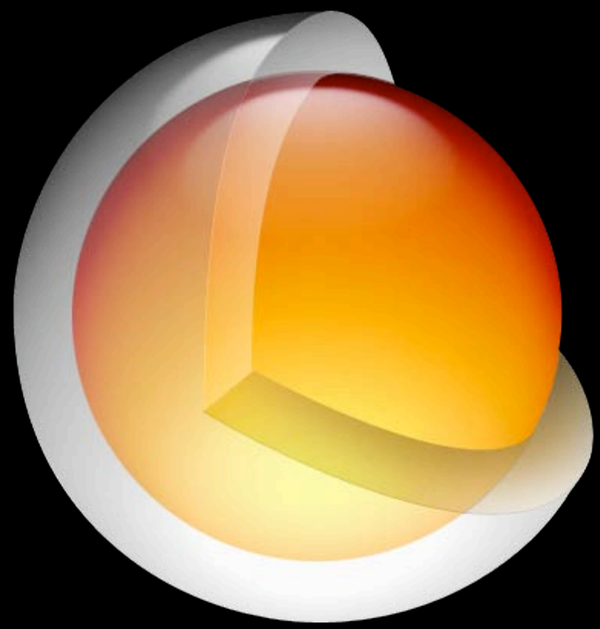
- Augment an implementation with additional features
- Query for Extensions at runtime
- Extension APIs linked dynamically
- Documentation about common Extensions on the OpenAL website

OpenAL: Extensions

- Determine if an Extension is present
  - `boolean alIsExtensionPresent(const ALChar* extName)`
- Get Extension function pointers
  - `void* alGetProcAddress(const ALChar* funcName)`

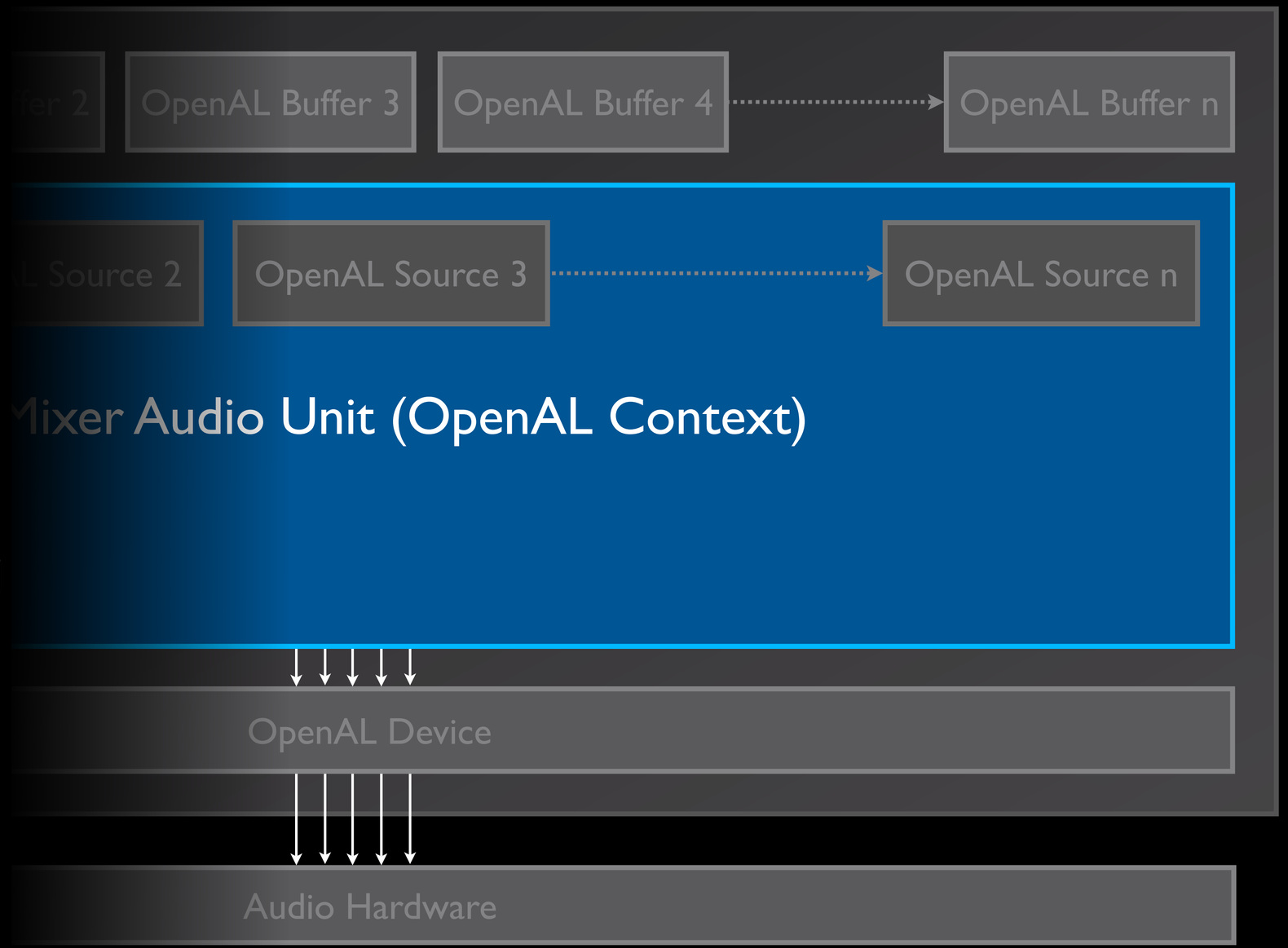
Benefits of Core Audio

- 3DMixer Audio Unit
- Default Output Audio Unit
- AudioConverter APIs
  (AudioToolbox.framework)



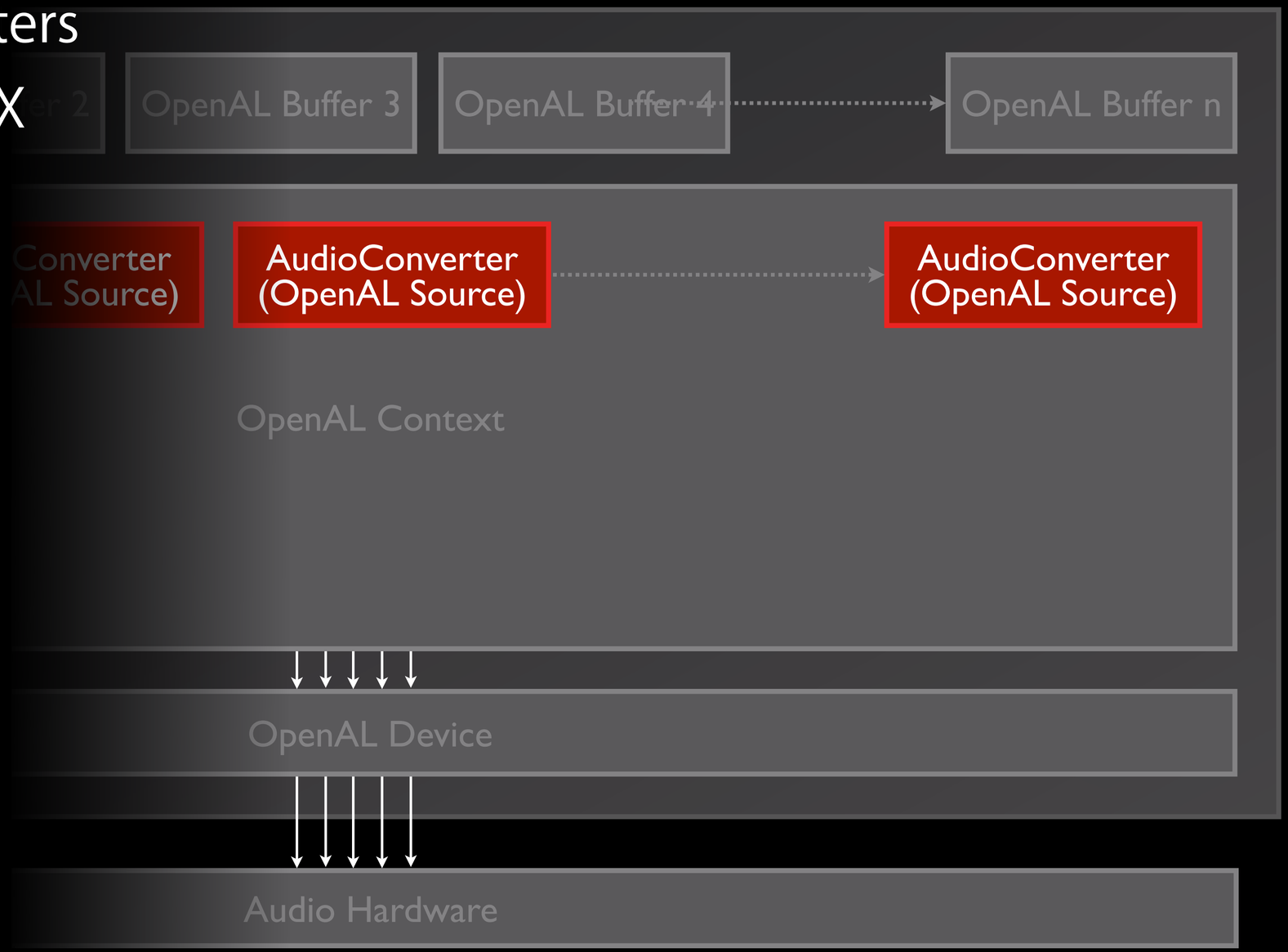
Core Audio: 3DMixer Audio Unit

- Mixing
- Spatial Rendering
- Supported Speaker Configurations
  - Stereo
  - Quadraphonic
  - 5.0
- Optimized Rendering



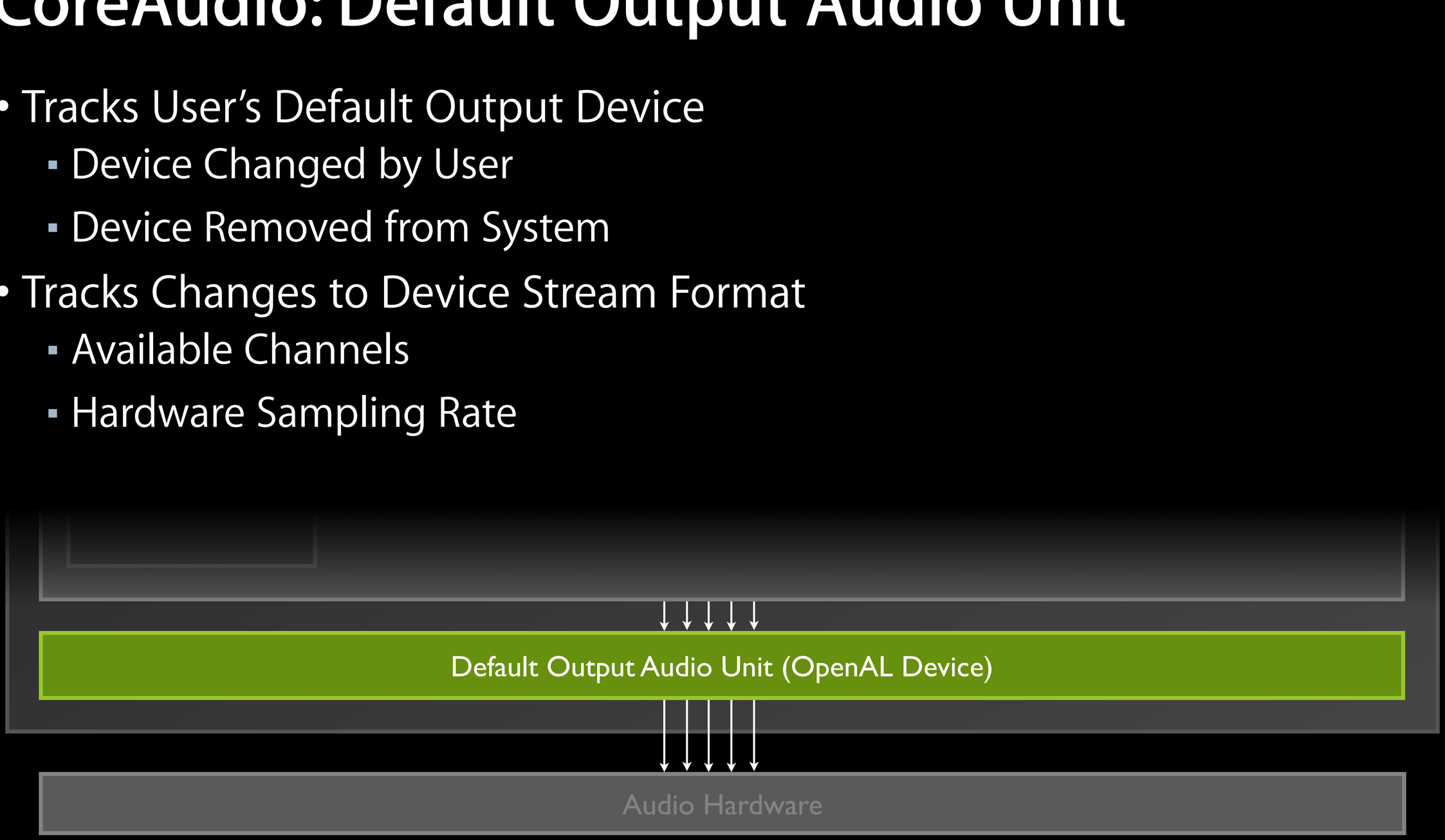
CoreAudio: AudioConverter

- Efficient Int/Float Blitters
- Supports an Mac OS X Supported Format



CoreAudio: Default Output Audio Unit

- Tracks User's Default Output Device
  - Device Changed by User
  - Device Removed from System
- Tracks Changes to Device Stream Format
  - Available Channels
  - Hardware Sampling Rate



Performance Test Results

Rendering 64 Sources (16-Bit PCM) simultaneously

		Non-Apple Implementation	Apple Implementation
G4 (1.3 GHz)	Stereo	24.3%	5.7%
G4 (1.3 GHz)	5.0	Unsupported	8.7%
G5 (2.5 GHz)	Stereo	9.2%	1.8%
G5 (2.5 GHz)	5.0	Unsupported	2.7%

- **% indicates CPU Load**

OpenAL for Mac OS X

Features

- OpenAL Implementation can take advantage of Core Audio features
  - `ALC_SPATIAL_RENDERING_QUALITY`
  - `ALC_RENDER_CHANNEL_COUNT`
  - `ALC_MIXER_OUTPUT_RATE`

OpenAL for Mac OS X: Features

ALC_SPATIAL_RENDERING_QUALITY

- Specify the 3DMixer's Rendering Quality
  - `ALC_SPATIAL_RENDERING_QUALITY_LOW:` Equal Power Panning
  - `ALC_SPATIAL_RENDERING_QUALITY_HIGH:` High Quality HRTF

```
// Use a high quality HRTF for rendering audio data
alSetInteger(ALC_SPATIAL_RENDERING_QUALITY, ALC_SPATIAL_RENDERING_QUALITY_HIGH);

// Get current render quality setting
ALInt   renderQuality = alGetInteger(ALC_SPATIAL_RENDERING_QUALITY);
```

Performance: Using HRTF

		No HRTF	Using HRTF
G4 (1.3 GHz PB)	64 Sources	5.7%	33.8%
	48 Sources		
	32 Sources		
G5 (1.8 GHz IMac)	64 Sources	5.0%	25.7%
	48 Sources		
	32 Sources		
G5 (2.5 GHz DP Tower)	64 Sources	1.8%	11.3%
	48 Sources		
	32 Source		

- % indicates CPU Load

Performance: Using HRTF

		No HRTF	Using HRTF
G4 (1.3 GHz PB)	64 Sources	5.7%	33.8%
	48 Sources	4.3%	24.9%
	32 Sources		
G5 (1.8 GHz IMac)	64 Sources	5.0%	25.7%
	48 Sources	3.8%	19.8%
	32 Sources		
G5 (2.5 GHz DP Tower)	64 Sources	1.8%	11.3%
	48 Sources	1.3%	8.4%
	32 Source		

- % indicates CPU Load

Performance: Using HRTF

		No HRTF	Using HRTF
G4 (1.3 GHz PB)	64 Sources	5.7%	33.8%
	48 Sources	4.3%	24.9%
	32 Sources	2.7%	15.4%
G5 (1.8 GHz IMac)	64 Sources	5.0%	25.7%
	48 Sources	3.8%	19.8%
	32 Sources	2.4%	13.1%
G5 (2.5 GHz DP Tower)	64 Sources	1.8%	11.3%
	48 Sources	1.3%	8.4%
	32 Source	0.95%	5.4%

- % indicates CPU Load

OpenAL for Mac OS X: Features

ALC_RENDER_CHANNEL_COUNT

- Force Rendering to Stereo
  - `ALC_RENDER_CHANNEL_COUNT_STEREO:` Render to stereo regardless of User's multichannel speaker configuration
  - `ALC_RENDER_CHANNEL_COUNT_MULTICHANNEL:` Render to the User's multichannel configuration

```
// Ignore user's multichannel speaker configuration and set rendering to Stereo
alSetInteger(ALC_RENDER_CHANNEL_COUNT, ALC_RENDER_CHANNEL_COUNT_STEREO);

// Get OpenAL's current Render Channel Count setting
ALIntrenderSetting = alGetInteger(ALC_RENDER_CHANNEL_COUNT);
```

OpenAL for Mac OS X: Features

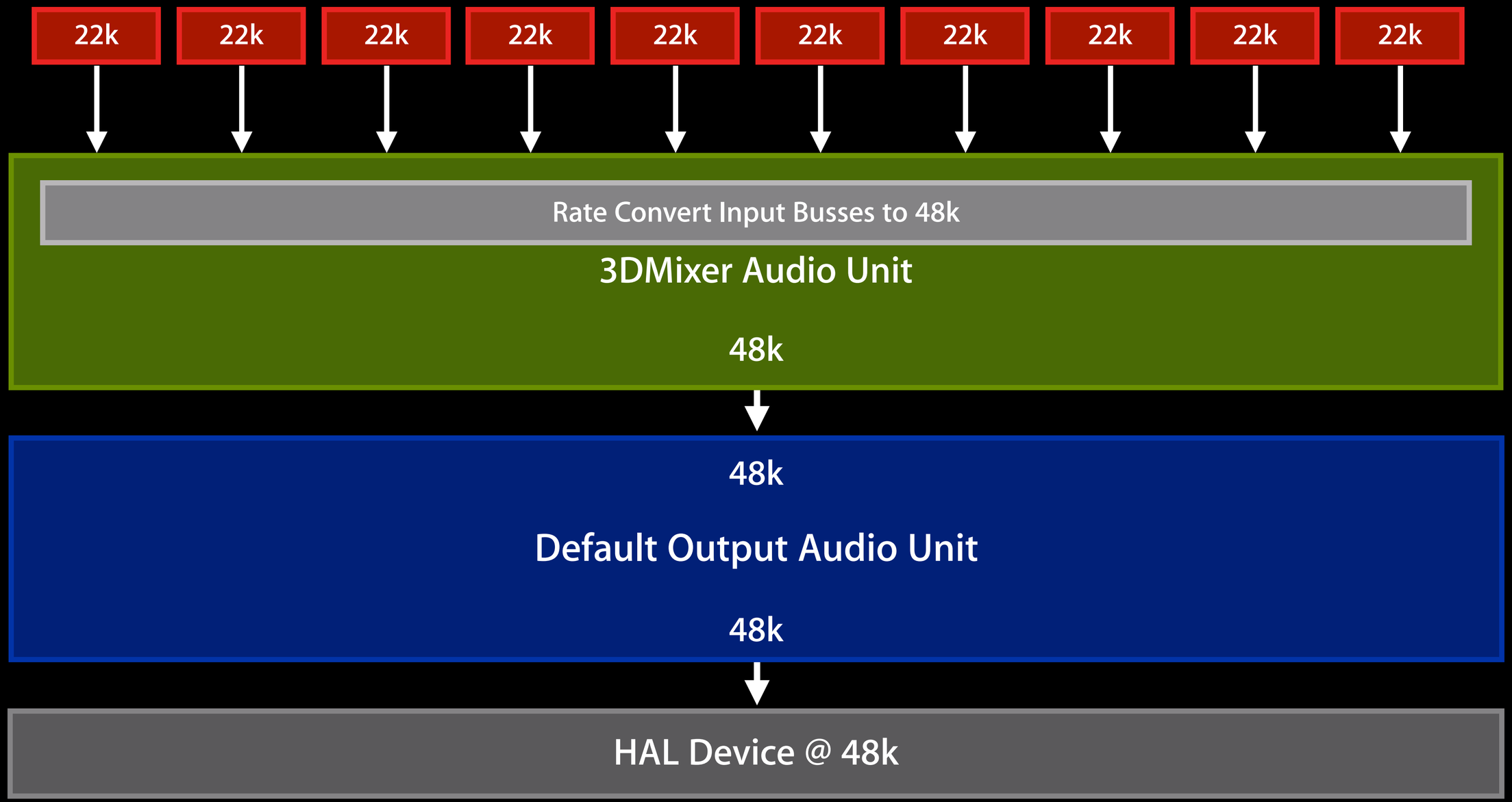
ALC_MIXER_OUTPUT_RATE

- Specify the Sample Rate at which audio data will be mixed

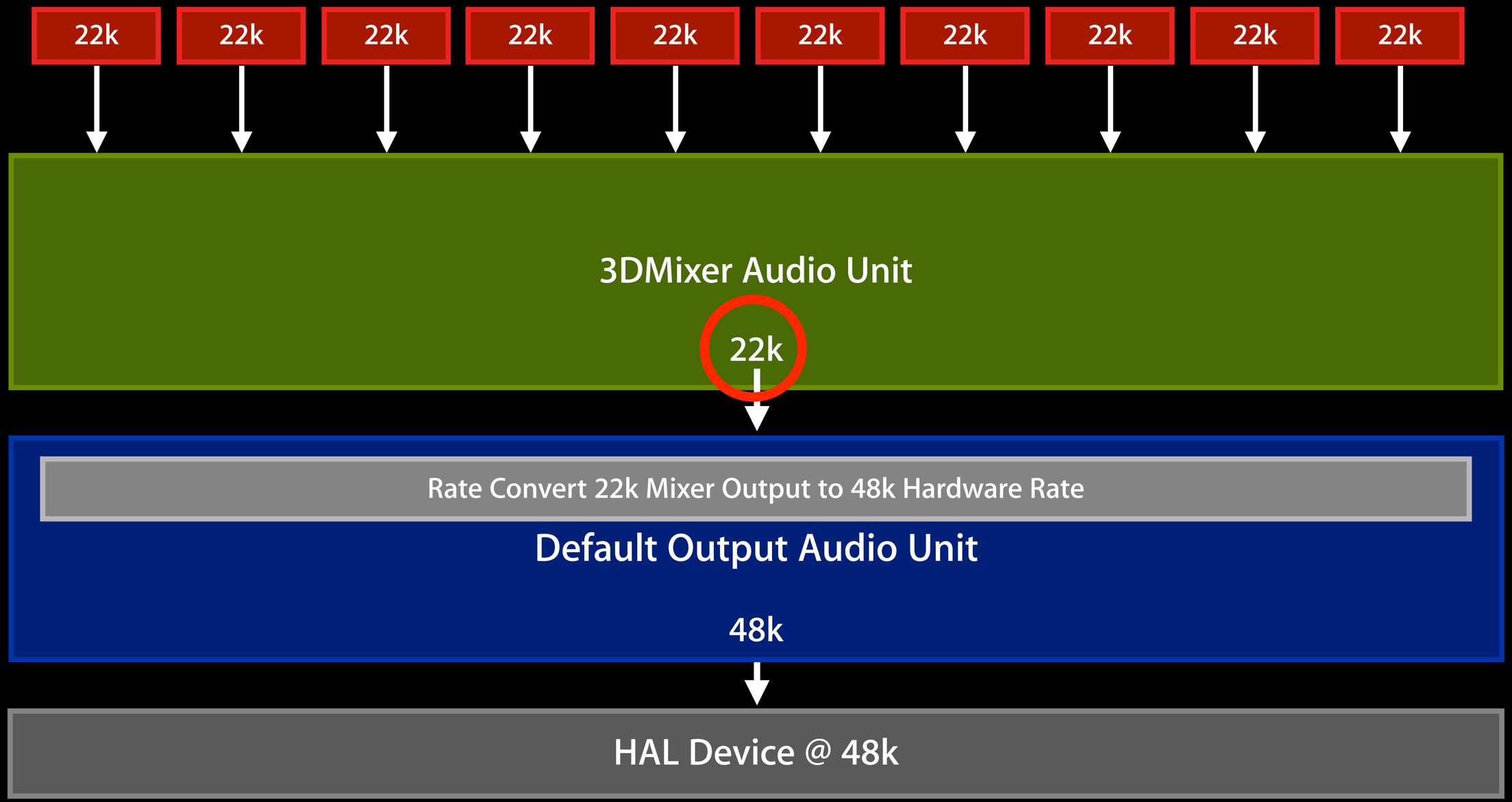
```
// Tell the 3DMixer to mix the data on all input busses at 22k
alSetDouble(ALC_MIXER_OUTPUT_RATE, 22050.0);

// Get current mixer mixing sample rate
ALdouble   mixerOutputRate = alGetDouble(ALC_MIXER_OUTPUT_RATE);
```

OpenAL: Mixing Sample Rate



OpenAL: Mixing Sample Rate



Demo

Doom 3

Glenda Adams
Aspyr Media Inc.

https://developer.apple.com/wwdc2005

More Information

https://developer.apple.com/wwdc2005

Documentation, Sample Code, and Other Resources

http://developer.apple.com/wwdc2005/

Related Sessions

Core Audio, Audio Units and OpenAL Lab	Graphics and Media Lab Wednesday 12:00PM

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OpenAL Website
Specification Documents
CVS Source Repository Links
http://www.openal.org/

OpenAL E-Mail List
http://opensource.creative.com/mailman/listinfo/openal

OpenAL Development E-Mail List
http://opensource.creative.com/mailman/listinfo/openal-devel

Q&A

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